High Fidelity Automated CFD meshing for the aerospace sector

Vangelis Skaperdas

BETA
SIMULATION SOLUTION

physics on screen

Advanced Modeling & Simulation Seminar Series
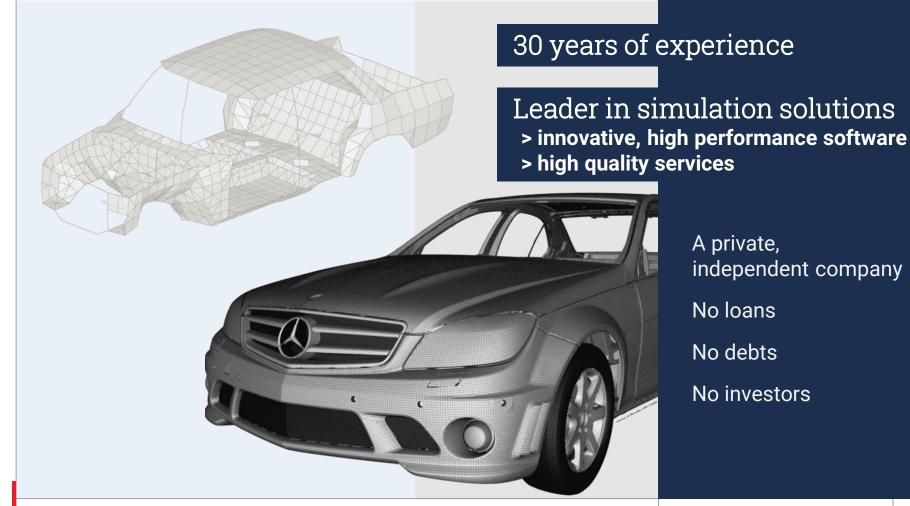NASA Ames Research Center June 15th 2021

Challenges to be addressed

✓Discretize the model accurately and efficiently

✓Automate the process of the CFD mesh generation, employing all best practices.

✓Generate meshes that satisfy strict quality criteria.

✓Make the whole meshing process invisible to the CFD engineer

✓Enable and facilitate quick model update

✓Generate and handle huge meshes

30 years of experience

Leader in simulation solutions
> **innovative, high performance software**
> **high quality services**

A private,
independent company

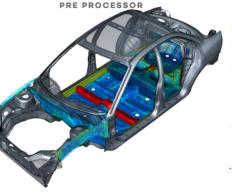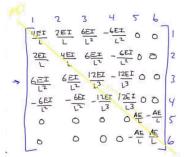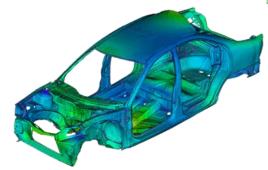No loans
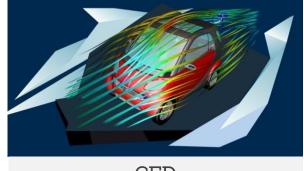
No debts

No investors

Our portfolio

Impact & Safety

Durability & Fatigue

CFD

NVH

Be empowered to achieve your goals for any analysis field, in a timely and effortless manner.

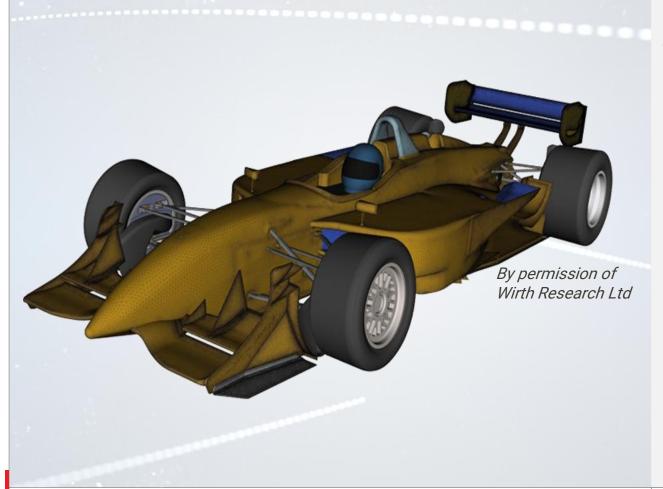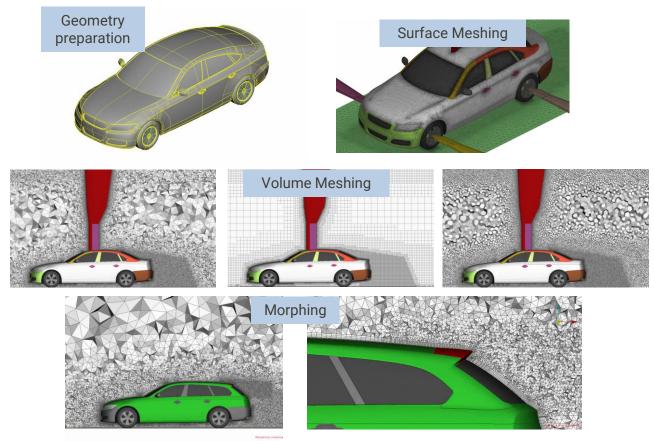Build common models and share them among your disciplines.

14
centers
worldwide

8
business
partners

BETA
SIMULATION SOLUTIONS

automotive	trucks & busses	motorsports	heavy machinery	rail vehicles
defense	aero-engineering	space		
maritime design	offshore	energy	industrial equipment	
power tools	robotics	electronics	biomechanics	architecture & construction

our business

82%
Land Mobility & Transportation

8%

5%

5%

ANSA pre-processor

Geometry handling

Meshing

Volume meshing

Output solver files

Morphing

Script language

Other tools

ANSA
PRE PROCESSOR

ANSA specifications

Supported platforms:
- Linux
- Windows

By permission of Wirth Research Ltd

✓ Parallel processing on multi core hardware for maximum speed

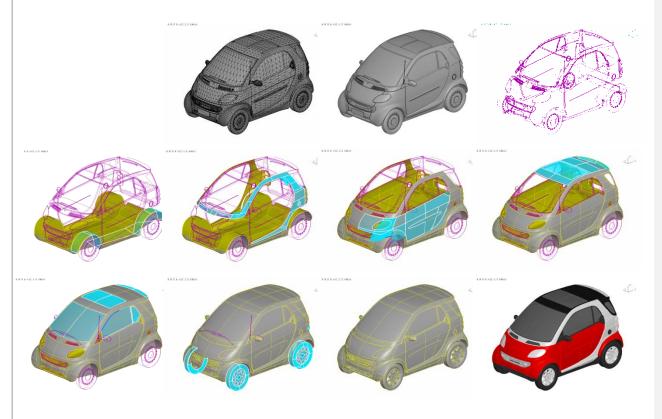✓ 64 bit code for unlimited memory usage

✓ Double precision for high accuracy

ANSA capabilities overview

Geometry preparation

Surface Meshing

Volume Meshing

Morphing

CFD formats:
Fluent
Star-CD/CCM+
OpenFOAM
CFD++
CFX5
SC/Tetra
CGNS
TAU
SU2
FUN3D
RavenCFD
CobaltCFD
PLOT3D
CMSoft AERO-F
UH-3D

CAD formats:
CATIA v4, v5, v6
Unigraphics NX
PTC Creo Parametric
JT
SolidWorks
Inventor
Parasolid
Rhinoceros
IGES
STEP

Input/Output:

Other formats:
PATRAN
STL
VRML
and more..

Direct Interfaces with other CAE codes:
TAITherm
THESEUS-FE
NASTRAN
ABAQUS
ANSYS
LS-DYNA
and more..
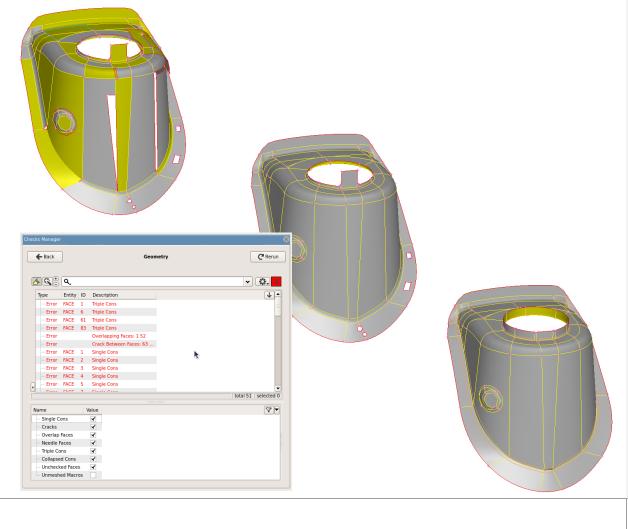
Geometry Handling

"CAD feel", easy-to-use functions for creation and manipulation of geometrical entities (points, curves, surfaces)

Advanced automatic and manual clean up tools

Cutting planes for model examination and cross section creation

Courtesy of PSA

Surface Meshing

Geometry handling

Surface Meshing

Volume meshing

Output solver files

Morphing

Script language

Other tools

ANSA
PRE PROCESSOR

Courtesy of PSA
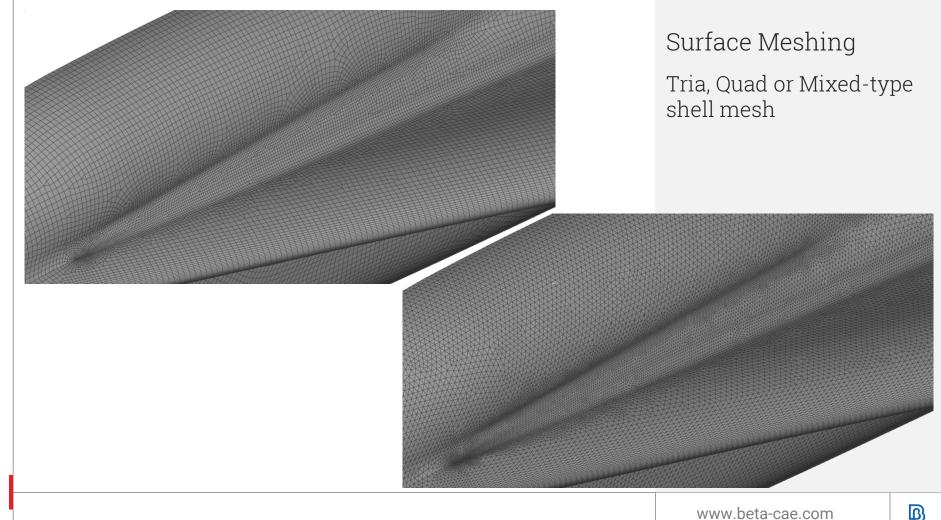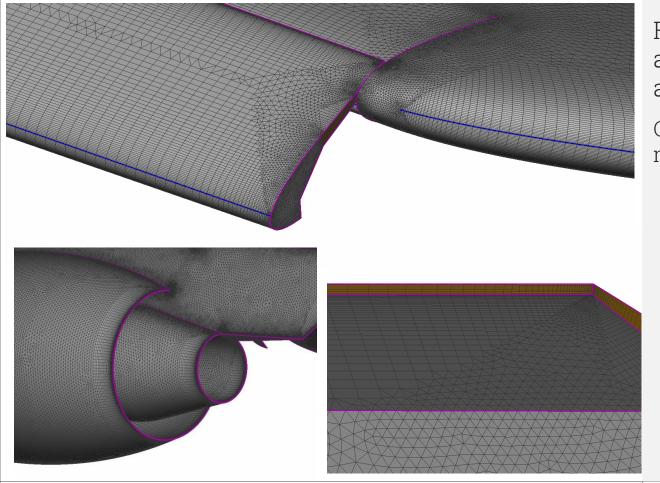
Surface Meshing for CFD

Fully automatic surface meshing resolving all curvatures, sharp edges, proximities and more..

Surface Meshing

Tria, Quad or Mixed-type shell mesh
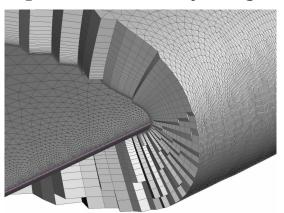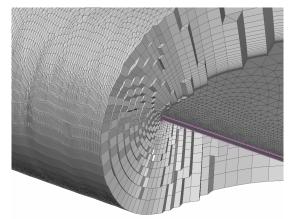
Fully automatic anisotropic mesh for aerospace applications

Quad or tria anisotropic mesh
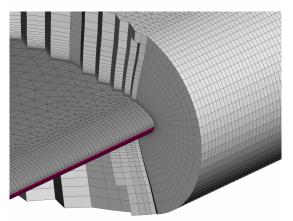
Effect of anisotropic mesh on layers generation
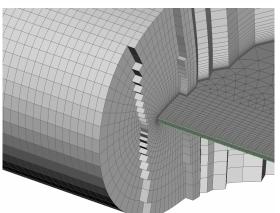
Isotropic mesh
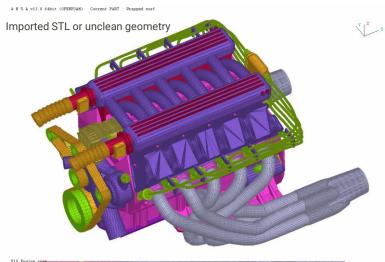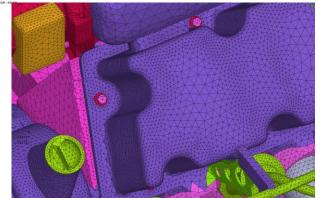
Anisotropic mesh
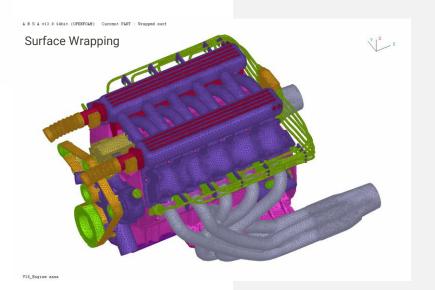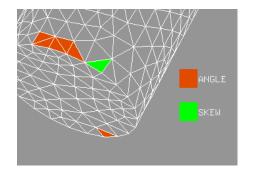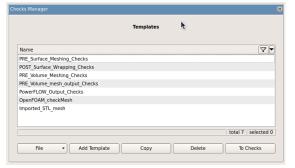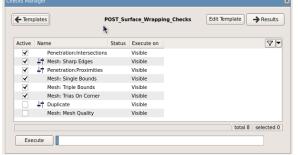
Surface wrapping

Variable length Wrapping, capturing local curvature and model feature lines

Imported STL or unclean geometry

Surface Wrapping

Surface mesh checks

Quality check according to multiple criteria (skewness, angle squish, length, aspect, warp, etc.) and solvers (Fluent, Star, OpenFOAM etc.)

Clear identification of poor-quality elements

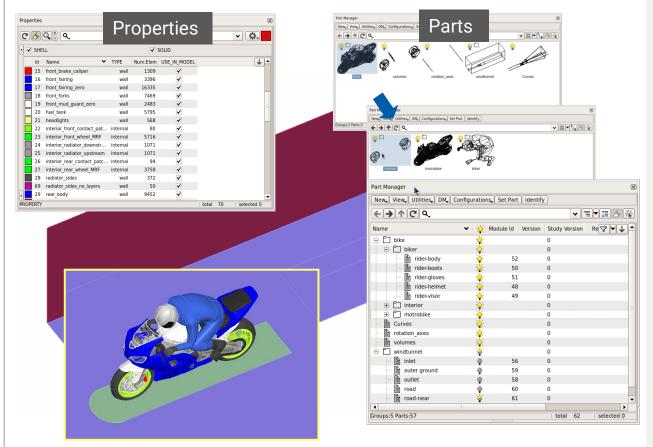Template controlled mesh integrity checks (locate unmeshed areas, free edges, proximities and penetration areas, duplicate elements etc.)

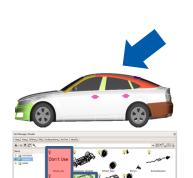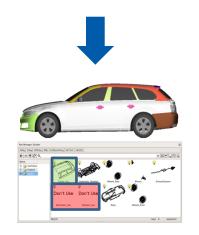Comprehensive mesh information and quality statistics

CFD model management

Double parallel model management tools: Properties (corresponding to CFD model zones) and Parts (assembly hierarchy extracted from CAD data)
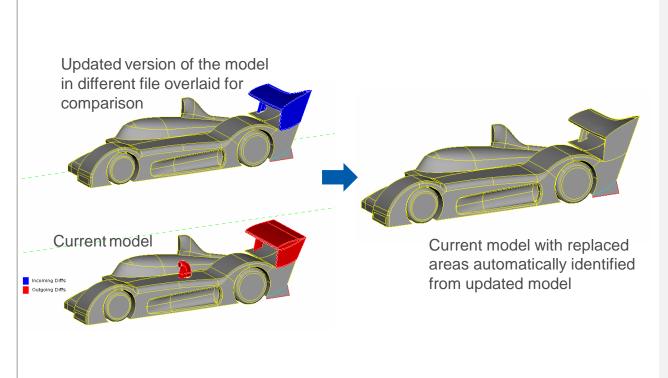
Configurations
management of
multiple variants

*DrivAer model courtesy of
Technical University of
Munich*

Updated version of the model in different file overlaid for comparison

Current model

Incoming Diffs
Outgoing Diffs

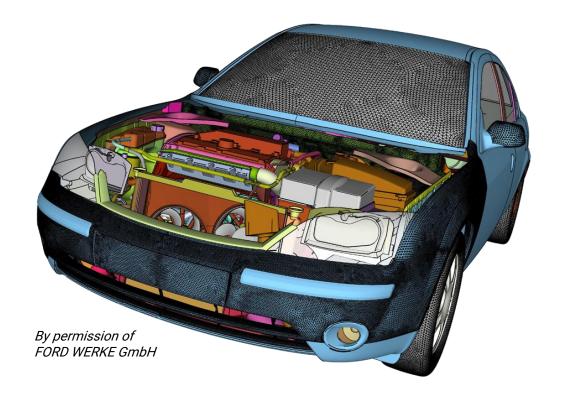Current model with replaced areas automatically identified from updated model

Advanced model comparison tool and local model updating

Functionality to compare current model with updates in other ANSA files, identify differences in geometry, or other attributes, and automatically update the current model with the necessary differences only
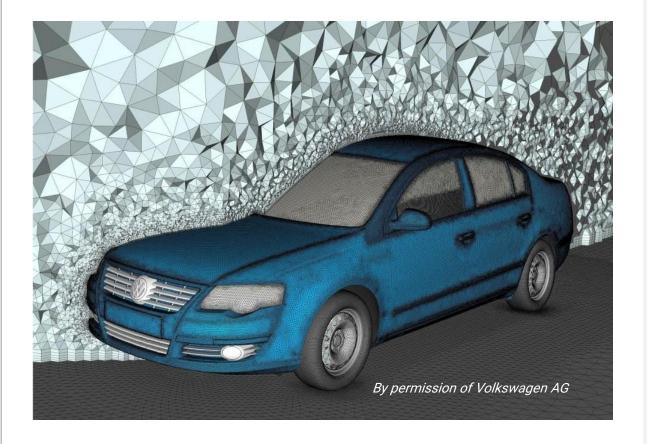
Volume meshing

Geometry
handling

Meshing

**Volume
meshing**

Output
solver files

Morphing

Script language

Other tools

ANSA
PRE PROCESSOR

Volume meshing

Fully automatic volume
and sub volume detection
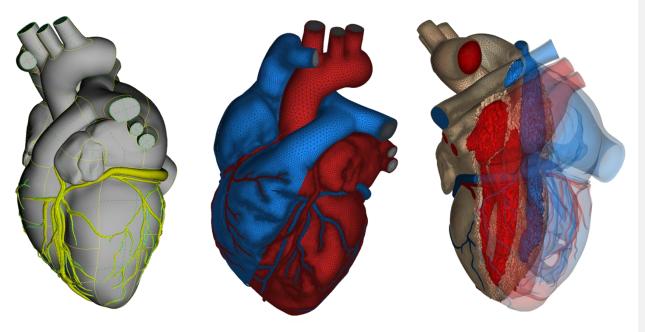applicable to the most
complex problems

By permission of
FORD WERKE GmbH
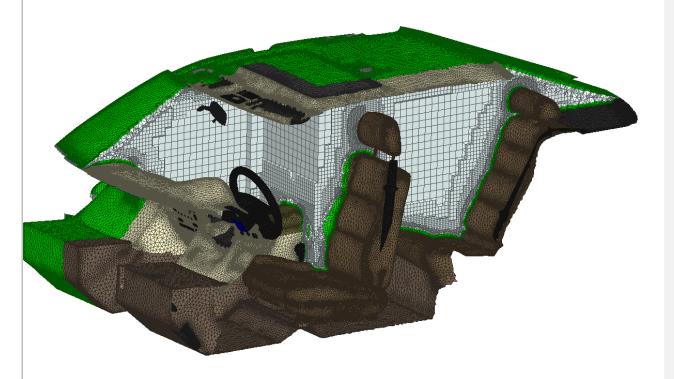
Volume meshing

Fast and robust volume meshing for all types of elements (tetra, pyramid, prism, hexa and polyhedron)
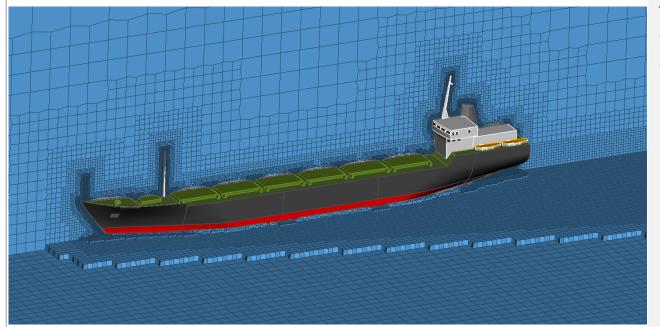

By permission of Volkswagen AG

Complete volume mesh of a human heart

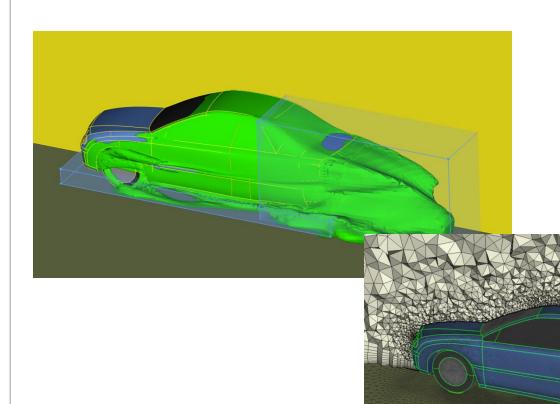2 million trias, 23 million prisms and tetras

Hexa-Interior volume meshing

Fully-conformal variable size Hexa-Interior mesh with prism and pyramid transitions
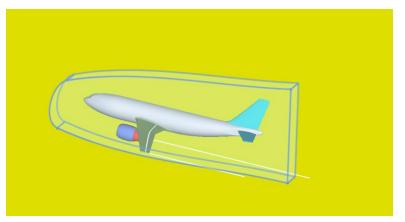
HexaPoly volume meshing

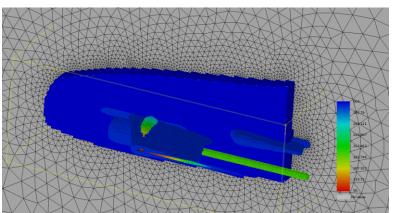Variable size hexa mesh with polyhedral elements for transitions

Size Field controls

Advanced functionality to control mesh size:

- Flexible Size Boxes
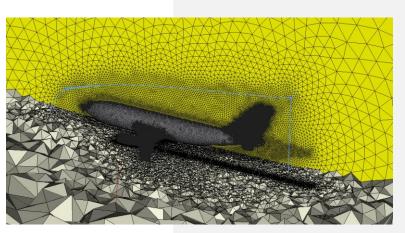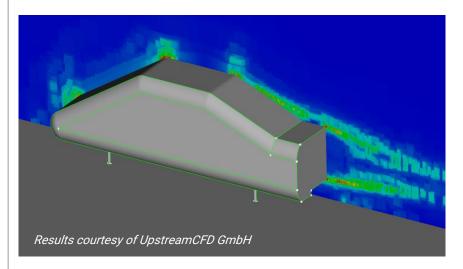- Closed iso-surfaces

Size Field controls

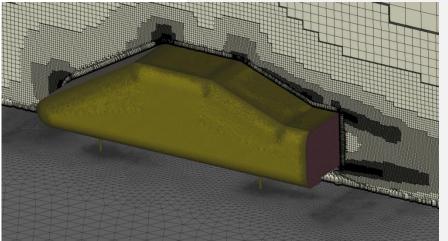Advanced functionality to control mesh size:

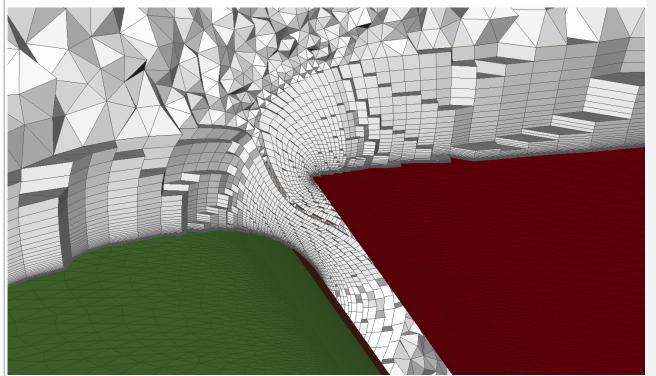- Offset surfaces
- Sweeping surfaces
- Point and Curve sources

Solution adaption

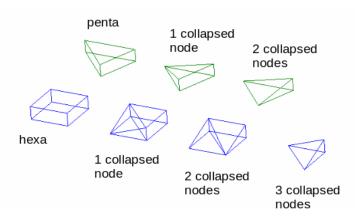Ability to read a size field from external solver and mesh based on the specified lengths

Results courtesy of UpstreamCFD GmbH

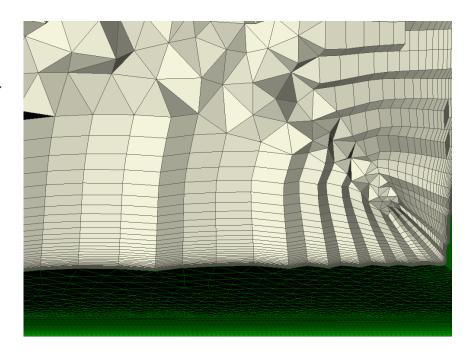# Robust layers generation at extreme heights and proximities

Powerful algorithm for very large total layer height and severe proximities
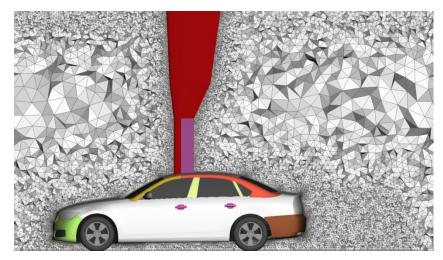
www.beta-cae.com
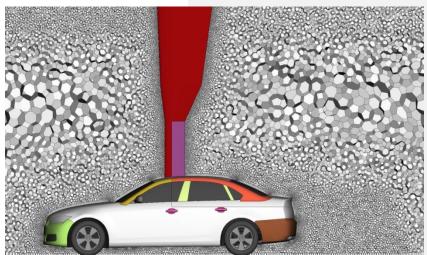
Layers generation options

- Generation of penta or hexa layers
- Variable growth rate per layer
- Different first height, growth rate and number
- Orthogonal near-wall layers
- Advanced smoothing algorithm
- Local layer squeezing at proximities
- Local layer collapsing at problematic areas
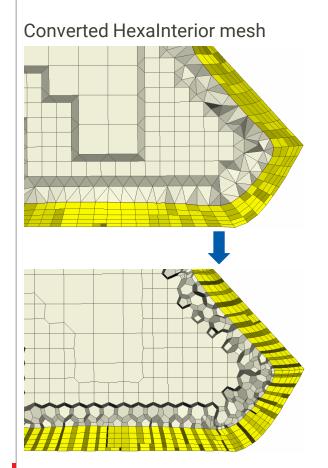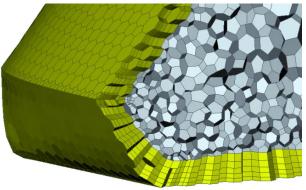- Controlled skew and warp of top cap

Conversion of hybrid meshes to polyhedral
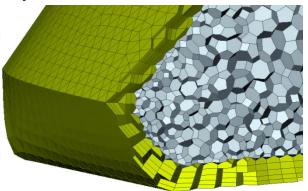
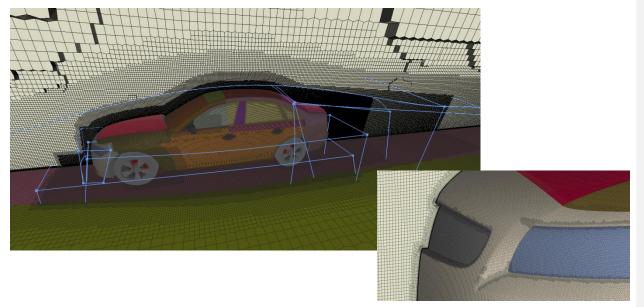Converted HexaInterior mesh

Converted tetra and layers

Layers excluded from conversion
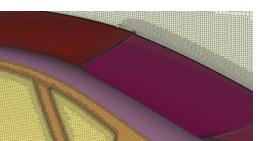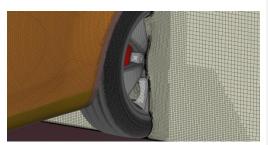
Polyhedral conversion options
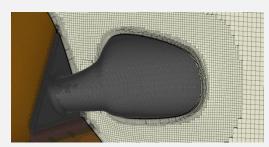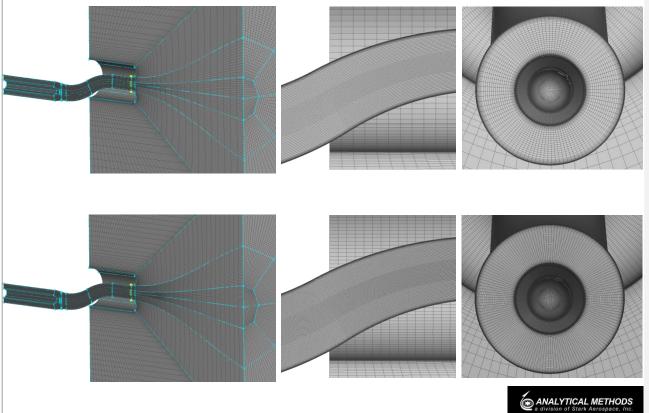
Hextreme volume meshing

Fully automated, highly controllable, trim hexa and polyhedral mesh generation without the need for watertight volume definitions, running on multi core hardware
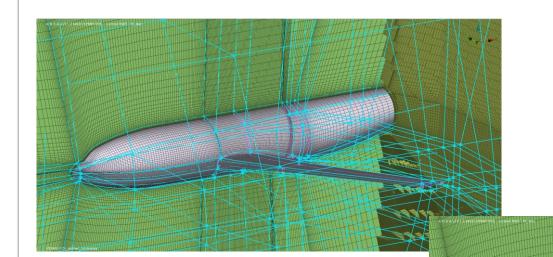
HexaBlock meshing

Numerical simulation of flow through S-duct - 1st Propulsion Aerodynamics Workshop

ANALYTICAL METHODS
a division of Stark Aerospace, Inc.
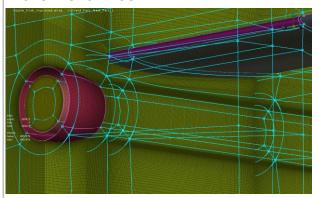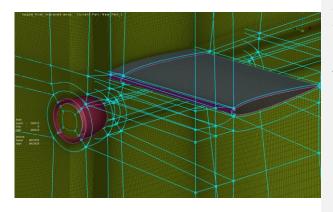
HexaBlock meshing

Hexa meshing external flows

www.beta-cae.com

Pure Hexa Mesh
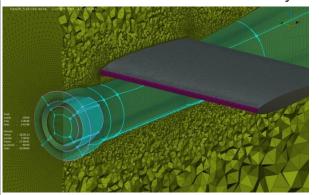
Combination of hexa mesh with hybrid mesh
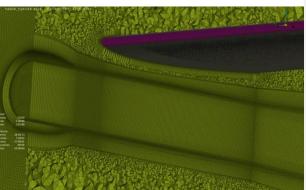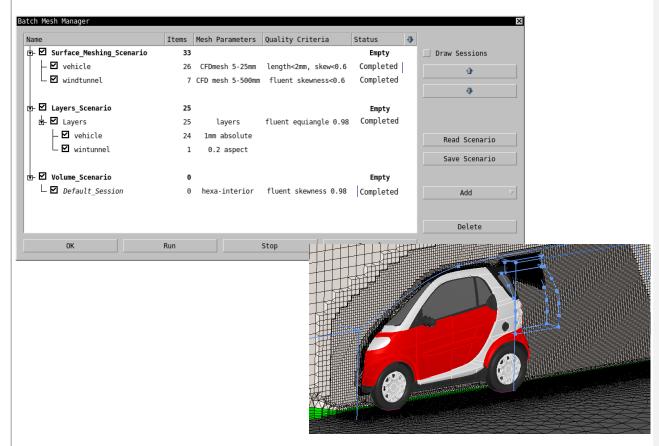
HexaBlock meshing of generic jet exhaust under wing

Batch Meshing tool for complete CFD mesh generation

Batch Mesh provides:
- Automation
- Consistency
- Mesh specs traceability
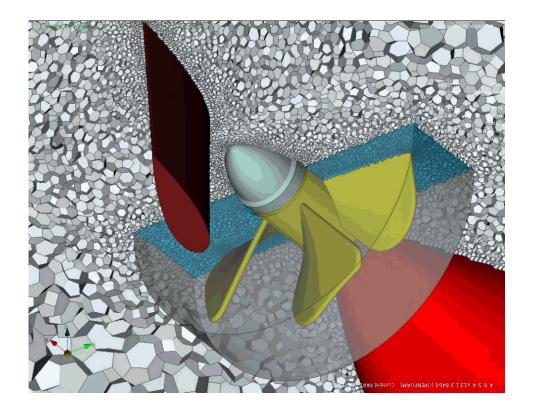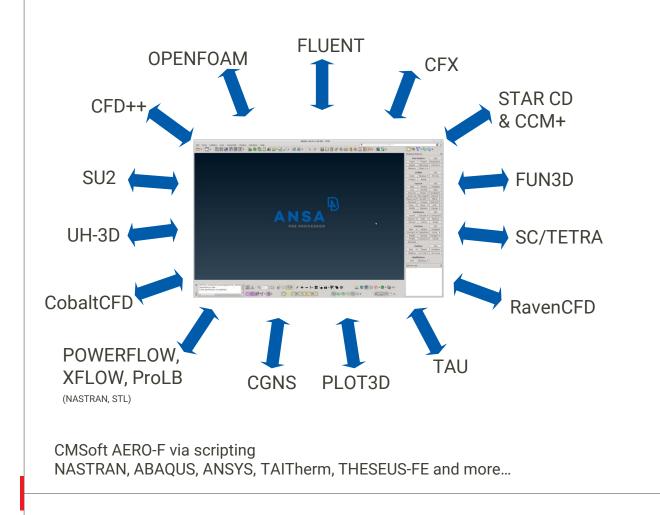
Morphing

Rear windscreen morphing

By permission of Volkswagen AG
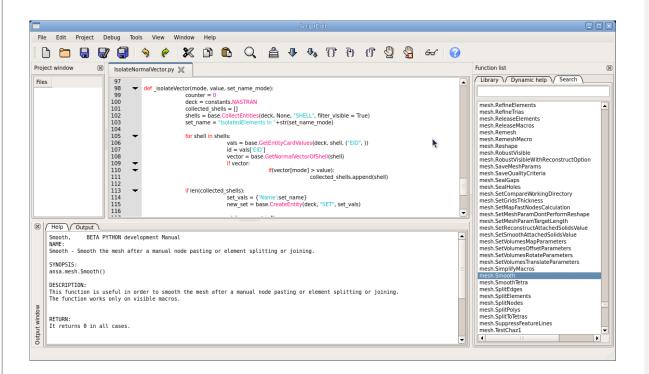
Morphing of ship rudder

One common pre-processing platform for all CFD solvers

OPENFOAM
FLUENT
CFX
CFD++
STAR CD & CCM+
SU2
FUN3D
UH-3D
SC/TETRA
CobaltCFD
RavenCFD
POWERFLOW, XFLOW, ProLB
(NASTRAN, STL)
CGNS
PLOT3D
TAU

CMSoft AERO-F via scripting
NASTRAN, ABAQUS, ANSYS, TAITherm, THESEUS-FE and more…

www.beta-cae.com

Script language

www.beta-cae.com

PYTHON scripting support

Creation of user defined functions through scripting for automation and customization of specific tasks, extending further the software's functionality

Build-in script editor for script creation, debugging and execution

PYTHON programming language support

Demo Cases
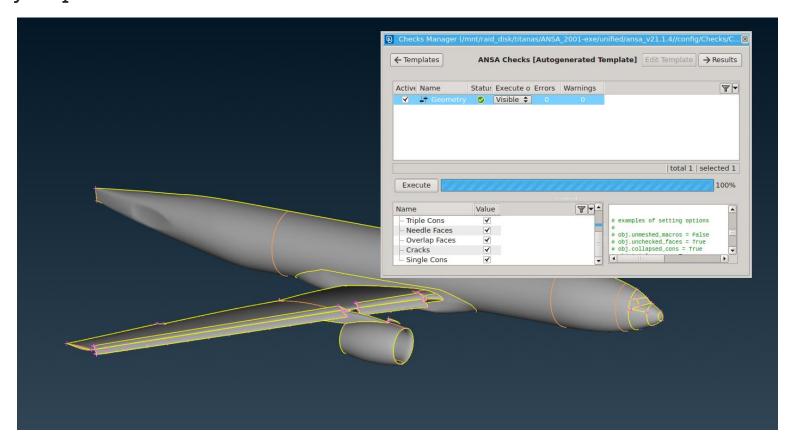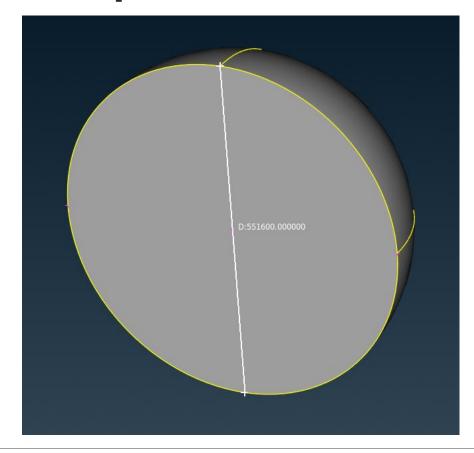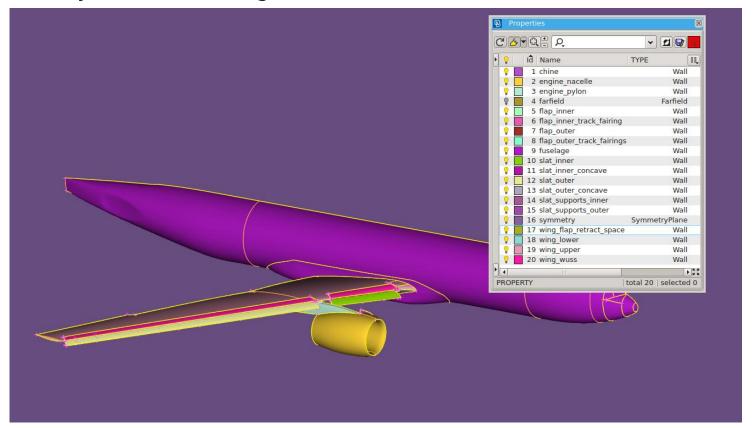
Geometry import and check of the HLPW-4 CRM model in STEP format

Creation of hemi-spherical flow domain

D:551600.000000

Boundary condition assignment

Detection and management of geometrical features

Special features like Leading and Trailing edges as well as sharp features are automatically detected based on user specified criteria. Features can also be edited manually if needed.
Special meshing rules (max. length, anisotropic mesh etc can be applied on them)

Setup of Batch Mesh tool

Batch Mesh tool in ANSA performs fully automatic surface and volume meshing based on predefined templates (scenarios and sessions). Each session contains different areas of the model and corresponding mesh settings.

Batch Mesh tool ensures:
- Automation (batch operation even in no GUI mode)
- Reusability of scenario templates for new geometries
- No user interaction and hence consistency in meshing
- Facilitates mesh refinement studies as all parameters can easily be scaled up or down
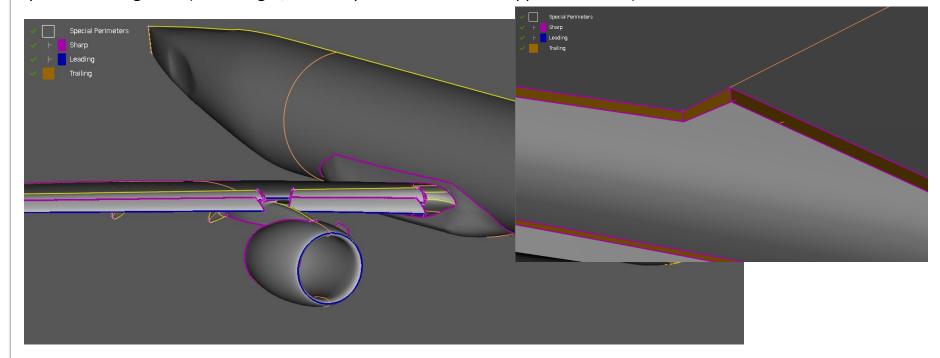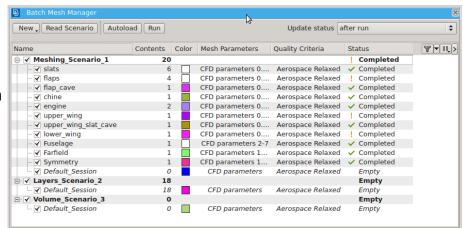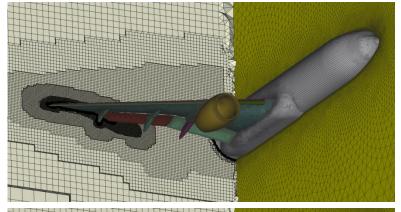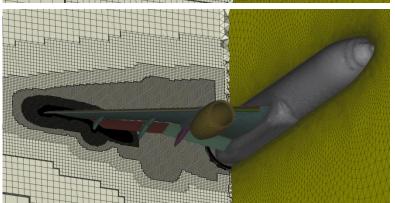- Mesh specs traceability as template is saved in ANSA file

Once a Batch Mesh scenario has been setup, it can be re-applied on any new geometry with minimum effort.

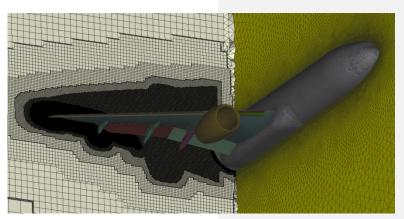| Batch Mesh Manager					
New ▾ Read Scenario Autoload Run				Update status	after run ▾
Name	**Contents**	**Color**	**Mesh Parameters**	**Quality Criteria**	**Status**
☑ **Meshing_Scenario_1**	**20**				! **Completed**
☑ slats	6	⬜	CFD parameters 0....	Aerospace Relaxed	✓ Completed
☑ flaps	4	⬜	CFD parameters 0....	Aerospace Relaxed	! Completed
☑ flap_cave	1	🟪	CFD parameters 0....	Aerospace Relaxed	✓ Completed
☑ chine	1	🟩	CFD parameters 0....	Aerospace Relaxed	! Completed
☑ engine	2	⬛	CFD parameters 0....	Aerospace Relaxed	✓ Completed
☑ upper_wing	1	🟪	CFD parameters 0....	Aerospace Relaxed	! Completed
☑ upper_wing_slat_cave	1	🟫	CFD parameters 0....	Aerospace Relaxed	✓ Completed
☑ lower_wing	1	⬜	CFD parameters 0....	Aerospace Relaxed	! Completed
☑ Fuselage	1	⬜	CFD parameters 2-7	Aerospace Relaxed	✓ Completed
☑ Farfield	1	🟩	CFD parameters 1....	Aerospace Relaxed	✓ Completed
☑ Symmetry	1	🟪	CFD parameters 1....	Aerospace Relaxed	✓ Completed
☑ *Default_Session*	0	🟦	*CFD parameters*	*Aerospace Relaxed*	*Empty*
☑ **Layers_Scenario_2**	**18**				**Empty**
☑ *Default_Session*	18	🟪	*CFD parameters*	*Aerospace Relaxed*	*Empty*
☑ **Volume_Scenario_3**	**0**				**Empty**
☑ *Default_Session*	0	🟩	*CFD parameters*	*Aerospace Relaxed*	*Empty*

Automated mesh
refinement study
HLPW 4 model

Level A: 91 million
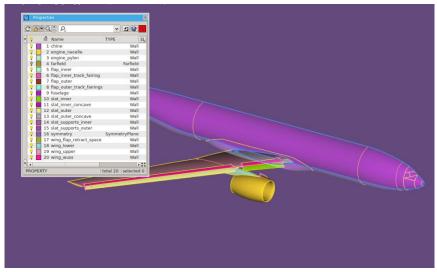Level C: 276 million
Level E: 723 million

Peak memory consumption during mesh generation 300Mb/million cells
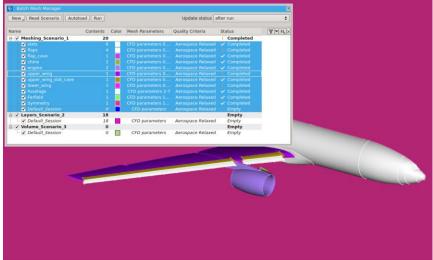Volume mesh generation speed over 250 million cells/hour

Setup of Batch Mesh tool

Different areas of the model automatically populate different Batch Mesh sessions (usually based on name filtering conventions) so that they are meshed with specific mesh parameters.
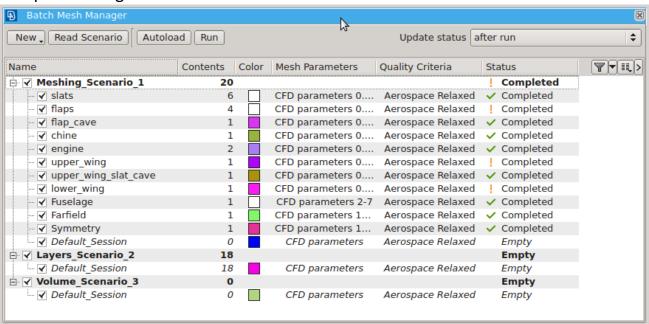
BC areas coloring

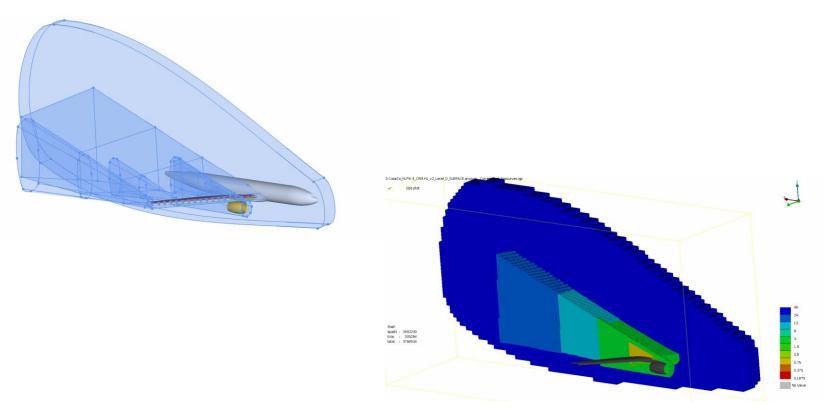Batch Mesh Sessions coloring

Setup of Batch Mesh tool

ANSA surface meshing uses powerful algorithms to automatically capture all the important geometrical features. The following features are included:

- Curvature refinement
- Sharp edge feature refinement
- Leading and trailing edges anisotropic meshing
- Proximity refinement
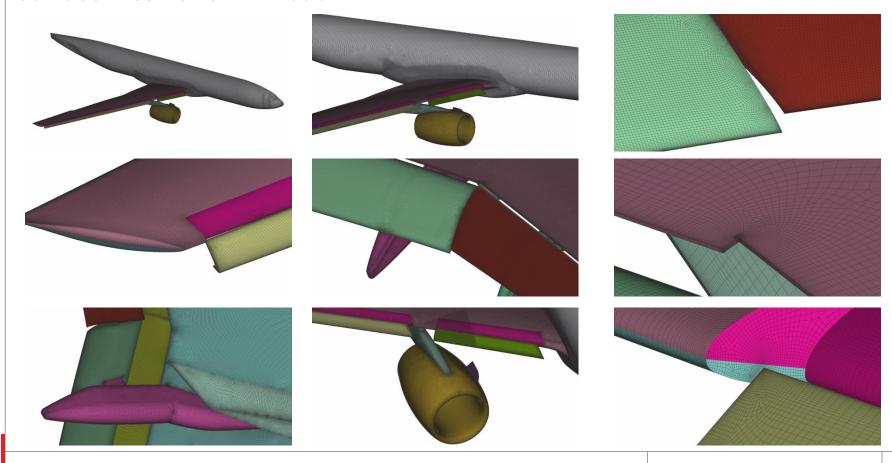- Size Fields for additional size constraint on the surface and volume mesh
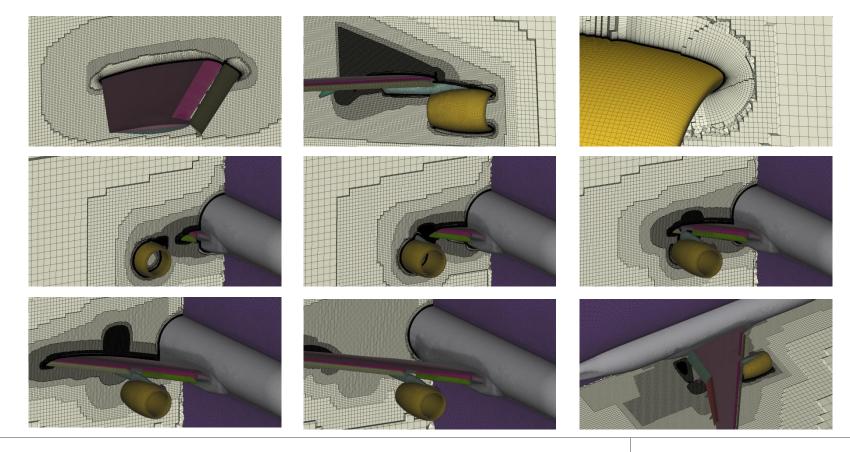
Definition of Size Field

Size Boxes and Size rules are defined in order to control the mesh size in the wake at high AoA
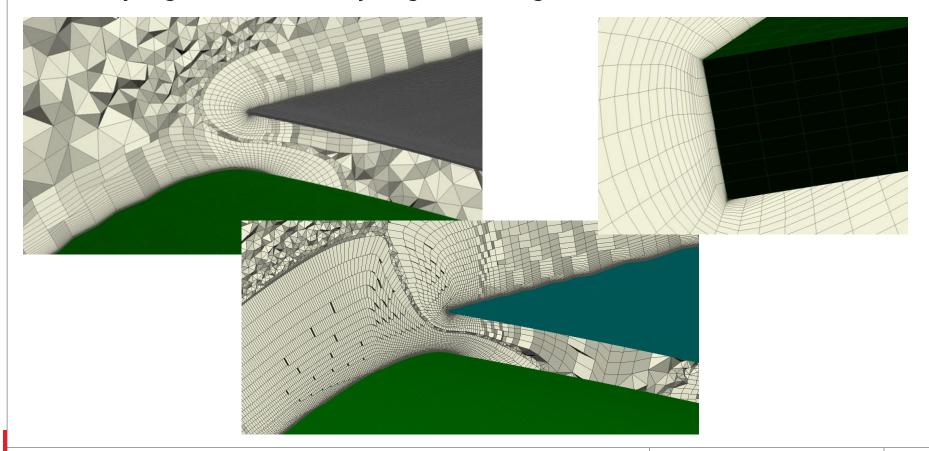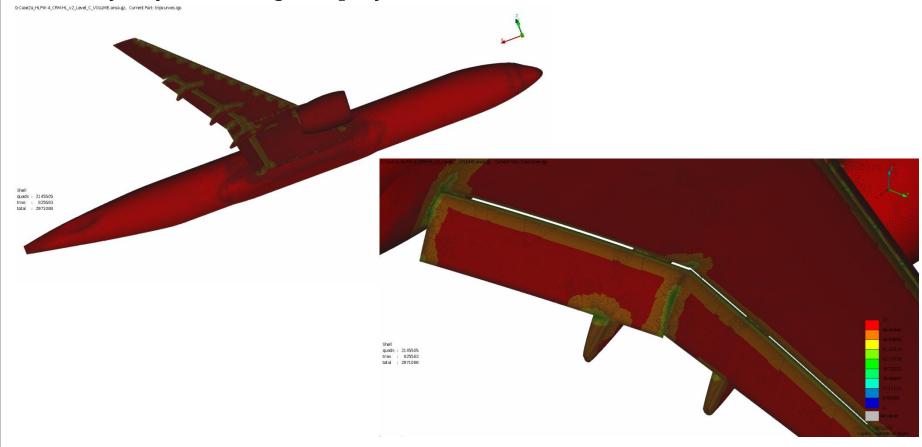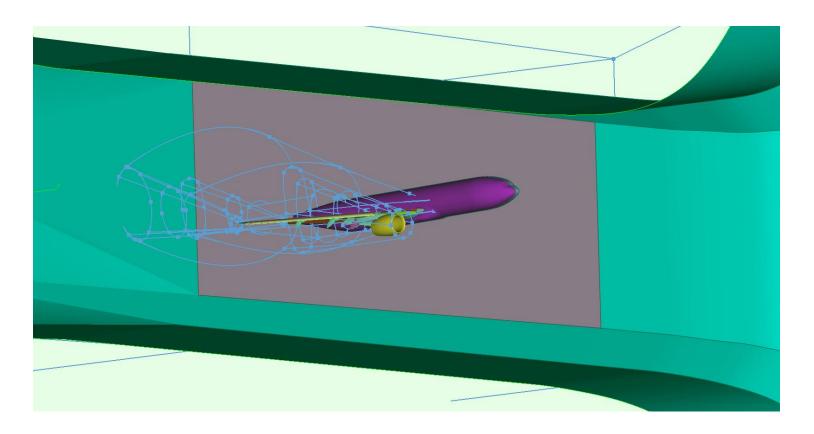
Surface mesh of CRM model

Volume mesh of CRM model

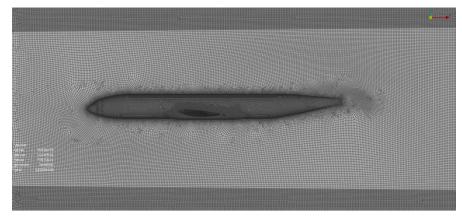# Robust layer generation at very large total heights
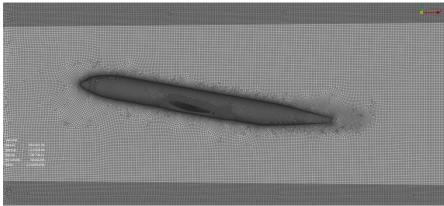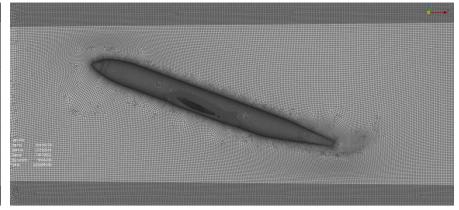
Boundary Layer coverage display

Morphing to change the AoA of the model in a wind tunnel

Morphing to change the AoA of the model in a wind tunnel

Morphing to change the AoA of the model in a wind tunnel

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